report from the

ATLAS Physics Workshop

ATHENS, Greece May 20-25, 2003
Part I: Summary of Standard Model Physics

- 250 participants
- 100 talks jammed into 35 hours over 4 days.

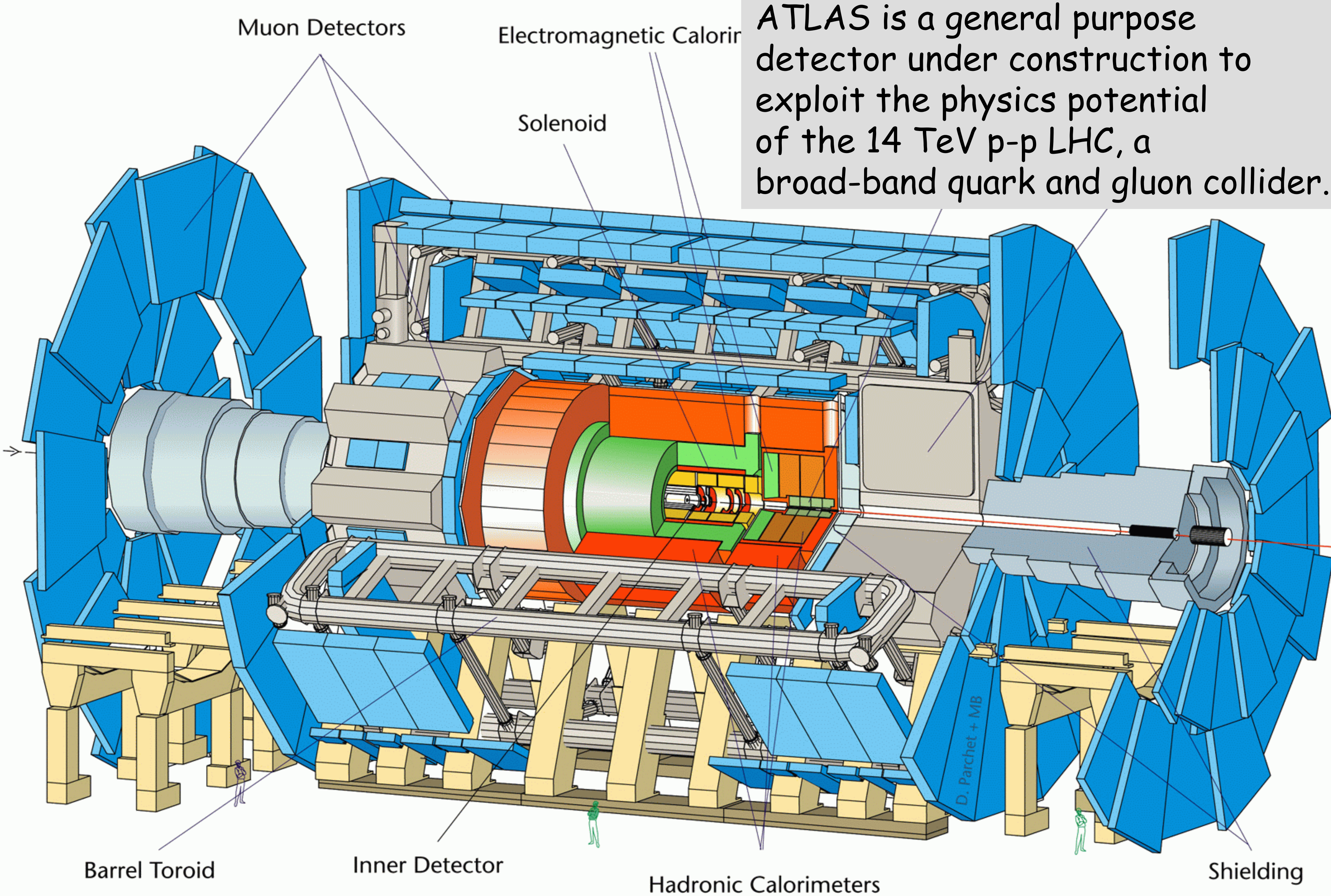
- Intro
- Detector Staging & Physics Commissioning
- EW, QCD, Top, Beauty physics
- The first year of physics
- … Davide to talk about Higgs, Exotics, Susy, Black holes, …

4th Physics Workshop
- Triest 1995
- Grenoble 1998
- Lund 2001

Physics Division
Berkeley Lab

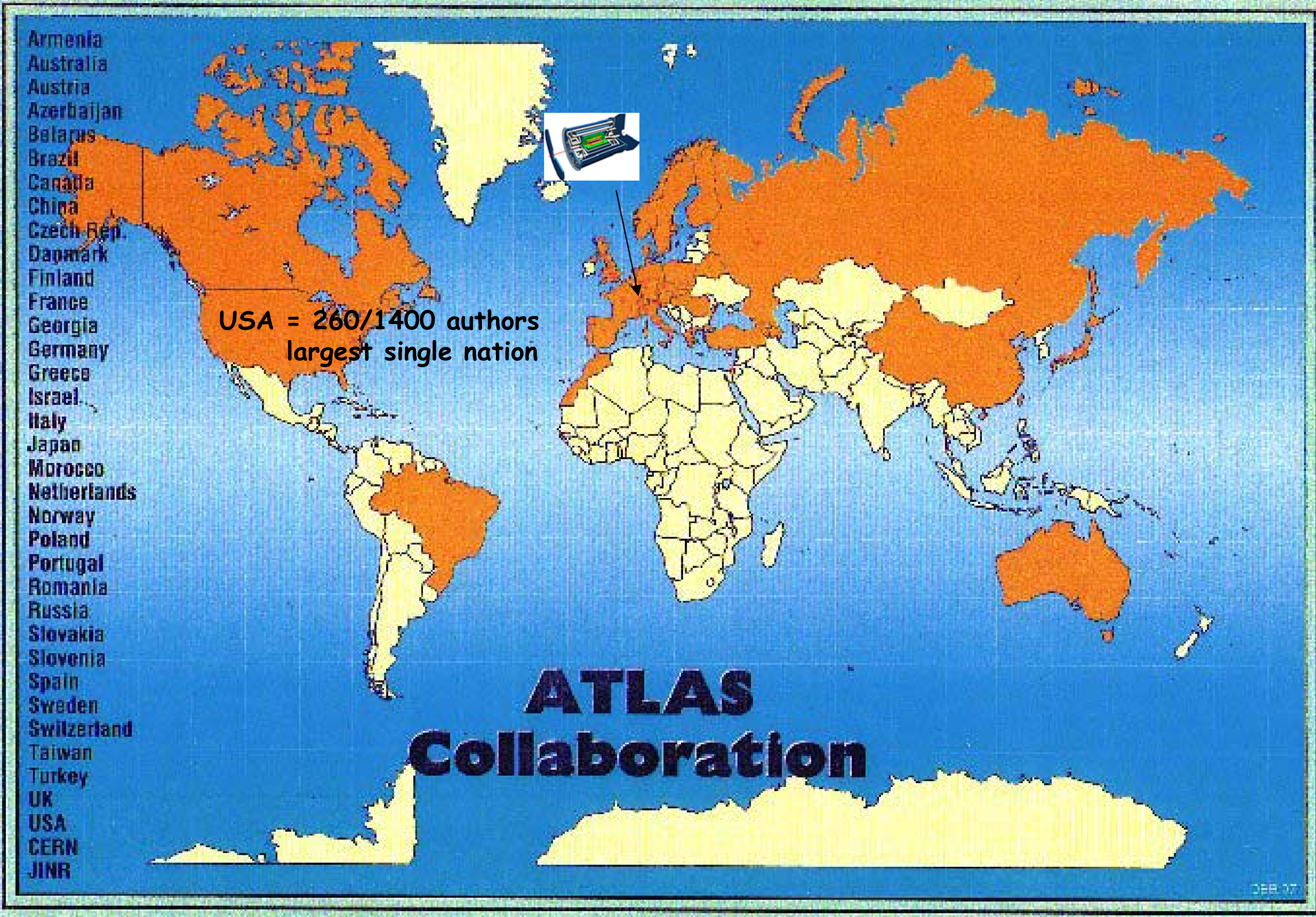
D712/mb-26/06/97

ATLAS is a general purpose detector under construction to exploit the physics potential of the 14 TeV p-p LHC, a broad-band quark and gluon collider.



The ATLAS Detector

34 Nations contribute to the ATLAS Collaboration



- Most significant changes in the detector layout since the 1999 TDR
  - pixel system is fully insertable (independent of ID)
  - All pixels are now the same size,
    - b-layer now uses z-pitch of 400 μm instead of 350 μm.
  - The beam-pipe grew, moving the pixel b-layer from 4.3cm to 5cm.
  - Enlarged central crack, holes for access and services.
- Machine parameters
  - "low luminosity" has doubled to $2 \cdot 10^{33}$ $cm^{-2}s^{-1}$

→ Changes affect B-physics programme most.

ATLAS cavern was handed over June 4, '03.

- **Cost to Completion 68.2 MCHF (≈$55M)**

  (construction completion, commissioning and integration)
- **Our resources: ~ 50 MCHF**
- **10-21.7 MCHF, have to be covered by redirecting resources from staging and deferrals**
  - Changes in the Initial detector layout
  - Changes in the trigger strategy
    - Trigger deferrals: less processors than foreseen
    - Event rate from LVL1 B-triggers has to be reduced
    - Full TRT track scan at LVL2 is not feasible→go to RoI-driven strategy at HLT even for the B-triggers

HLT Staging: New Trigger Levels

Reminder: major changes (LVL1 and HLT)

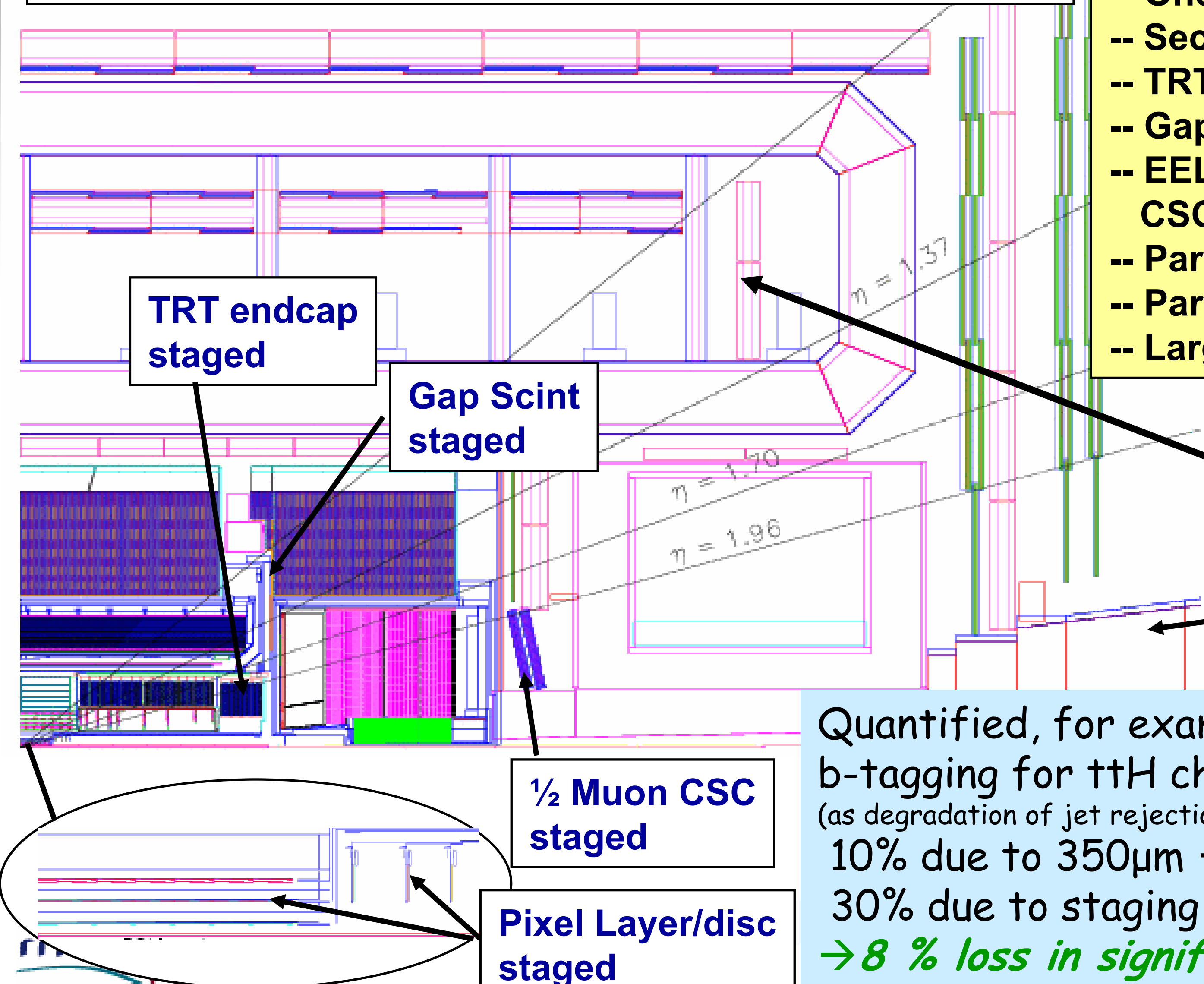
→ e20i	→ e25i	→ 3J75	→ 3j165
→ γ40i	→ γ60i	→ 4J55	→ 4j110
→ MU6	→ MU20	→ j50+xE50	→ j70+xE70
→ J180	→ j400	→ τ20+xE30	→ τ35+xE45
→(none)	→ 2J350		

+ prescaled triggers.

- single muon "B-physics" trigger is essentially gone.
  - left with B→μμ rare decays and B→ J/Ψ(→μμ)K^0
  - bad in particular for channels not accessible at B-factories, $B_S \to D_S \pi$
- NO safety margin in LVL 1 bandwidth for high-P_T physics. *(formerly factor 2 safety margin)*
- jet triggers now at the limit for overlap with Tevatron
  - CDF/D0 dijet mass reach 700-1000 GeV for 15 fb^{-1}

Detector Staging ("initial detector")

Staged components for the initial physics run



Staged/deferred components:

- -- One pixel layer at 11cm
- -- Second pixel disk absent
- -- TRT outer endcaps "C"
- -- Gap scintillator
- -- EEL/EES MDT and half CSC layers
- -- Part of forward shielding
- -- Part of LAr ROD
- -- Large part HLT/DAQ CPUs

staging affects b-physics most

Quantified, for example in b-tagging for ttH channel
(as degradation of jet rejection for a given efficiency)
10% due to 350μm →400 μm pixels
30% due to staging of pixel layer
→8 % loss in significance… requires 15% more luminosity to compensate.

Commissioning

4 June 2003: UX15 Cavern transferred to ATLAS

Phase A
System at ROD level.
Systems for LVL1, DCS and DAQ.
Check cable connections.
Infrastructure.
Some system tests.

Phase B
Calibration runs on local systems.

Phase C
Systems/Trigger/DAQ combined.

"Physics Commissioning"

Apr 2007: first circulating LHC beam

Aug 2006: Detector fully installed in the cavern

Phase D
Global commissioning.
Cosmic ray runs.
Initial off-line software.
Initial physics runs.

8/03 | 12/04 | 03/06 | 10/06

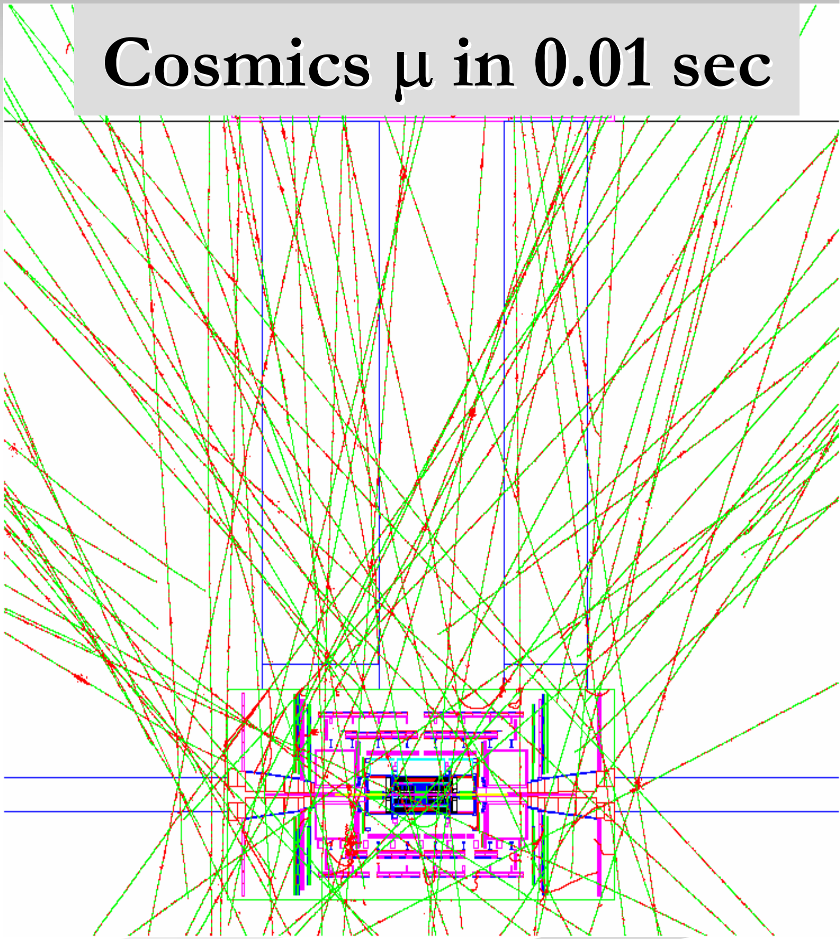
Physics Commissioning

- PHASE D: Global detector commissioning
  - Cosmic run (40 days, end of 2006)
  - One beam circulating in the machine (~ 2 Months, APR 2007)
    - beam/gas interactions
    - beam halo
  - First collisions (mid-late 2007)
    - in situ physics control samples: e.g. Z→ee, μμ, tt→semileptonic
- Commissioning our understanding of the Physics at 14 TeV
  - event rates (remember there is NO margin left in the trigger)
  - Gluon PDF at high x
  - basic SM processes: *covered later*
    - minimum bias, underlying event, global event properties
    - measure W,Z,tt, QCD jets cross sections to 10-20%
    - measure W mass, top mass to few %

Commissioning with Cosmics

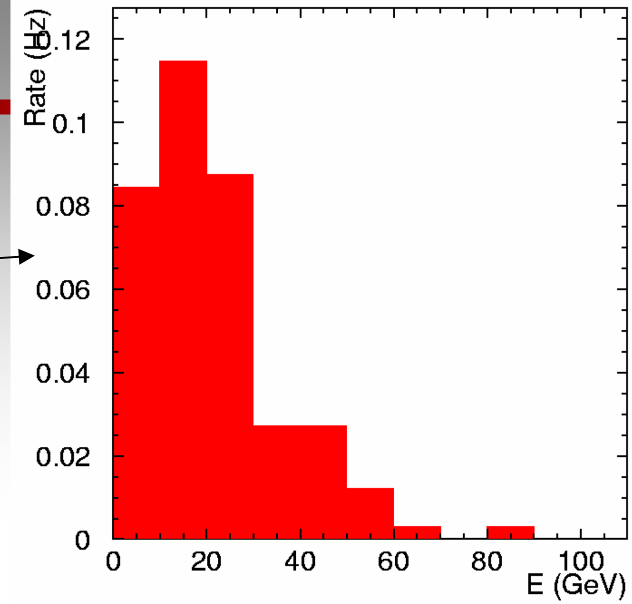
- 40 days of cosmic running end 2006
  - electronics and DAQ shake down
  - map dead cells
  - first real test of reconstruction Software
  - commission LVL1 trigger
  - test track finding in HLT
  - muon resolution
  - Calorimeter EM energy scale
- Full G3 simulation in place, includes ATLAS, caverns, surface bldgs, etc.
- Trigger= LVL 1 RPC with timing adjustments

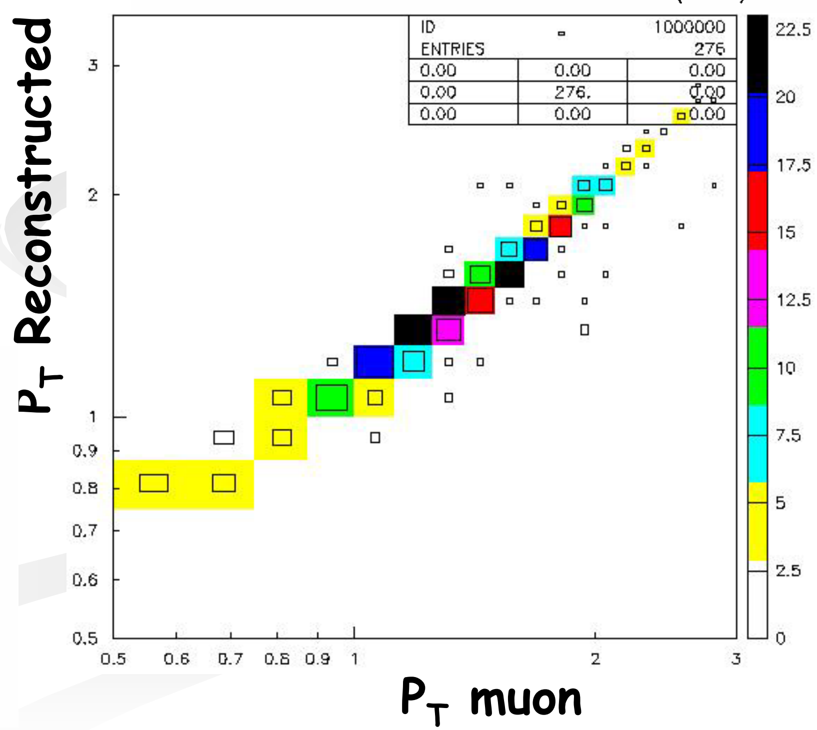
Cosmics μ in 0.01 sec

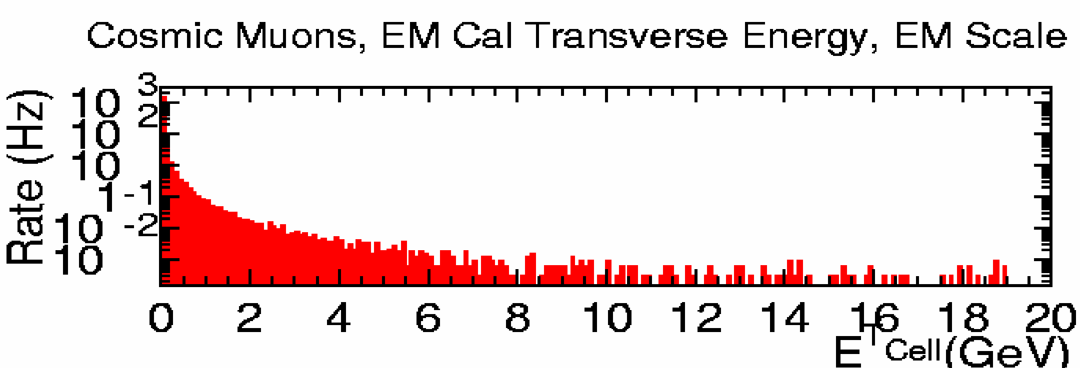


Commissioning with Cosmics

- rate of through going muons with RPC & pixel hits is >> 0.1 Hz.
- Cosmics FULL Simulation
  - 3 M muons entering ATLAS hall
  - 300 events with signals in pixels
  - 276 reconstructed tracks in MuSpec(Muonbox)
  - Rate in EM calorimeter with E_T(cell) > 5 GeV is 0.7 Hz.







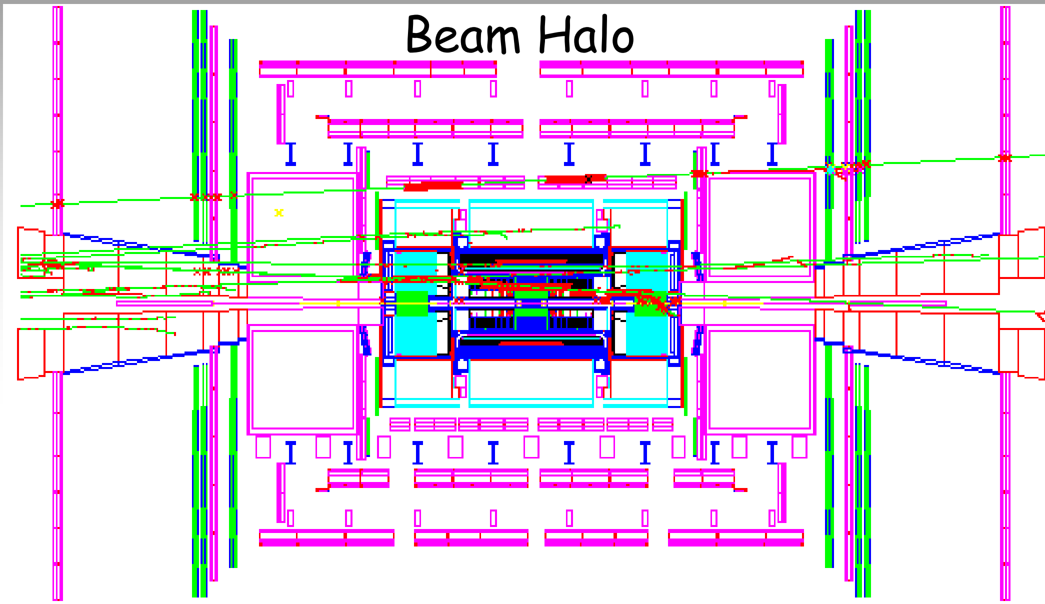
Beam Halo / Beam Gas Collisons

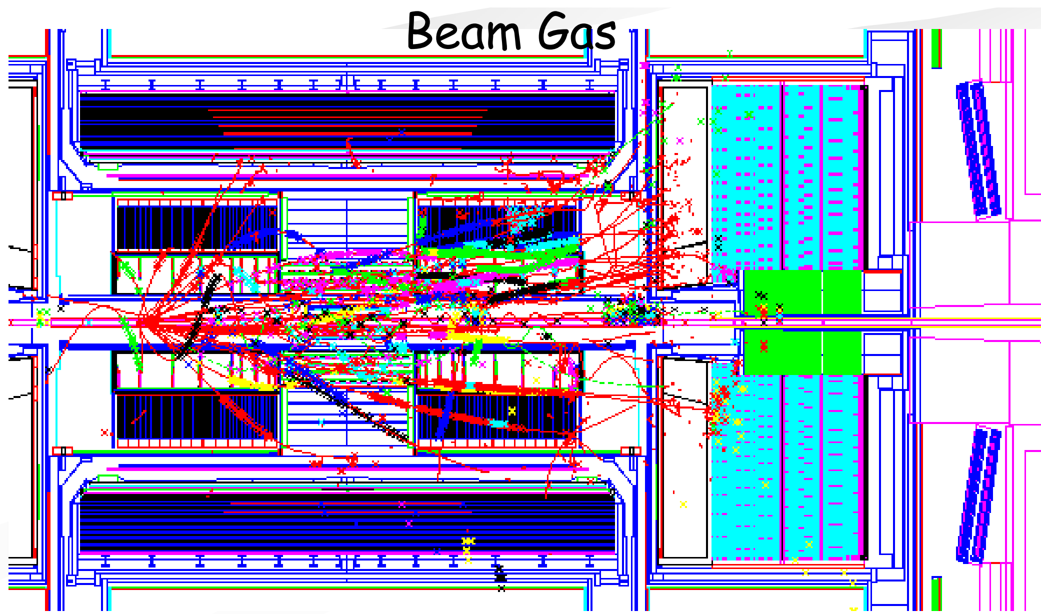
- Beam halo rates are large, triggering can be difficult.

Particle	Rate
All	1750 kHz
$h^{\pm}$	1515 kHz
n	130 kHz
μ	105 kHz
μ, E>10 GeV	16 kHz
μ, E>0.1 TeV	1 kHz
μ, E>1 TeV	10 Hz

Triggered Beam Halo Muon Rate

Detector	Rate (F.On)
MDT endcap	136,0 Hz
Pixel	0,015 Hz
SCT	0,1 Hz
TRT	0,2 Hz
EM, HEC	0,5 Hz
Tile	41 Hz





Heavy Ions (15:30->16:10)

Chair: Takai, H.
Location: Athens University

15:30	Event characterisation, tracking, Y --> mu-mu (25') (more information)	**Wosiek, B.** *(INP Cracow)*
15:55	Jet quenching (15') (transparencies)	**Assamagan, K.** *(BNL)*

Forward physics (16:10->16:30)

Chair: Takai, H.
Location: Athens University

16:10	ATLAS potential for Forward Physics (20') (transparencies)	**Rijssenbeek, M.** *(Stony Brook)*
16:30	Coffee break	

Standard Model physics (17:00->18:30)

Chair: Dobbs, M. and Tapprogge, S.
Location: Athens University

17:00	Introduction (15') (transparencies)	**Dobbs M., Tapprogge S.** *(LBNL, Helsinki)*
17:20	Minimum Bias and Underlying Event (20') (transparencies)	**Moraes, A.** *(Sheffield)*
17:40	PDFs for the first year of ATLAS physics (20') (transparencies)	**Butterworth, J.** *(UCL)*
18:05	WW scattering in the absence of a light higgs (15') (transparencies)	**Cox, B.** *(Manchester)*
18:20	Wavelet analysis of VHM events in ATLAS (10') (more information)	**Uzhinsky, V.** *(JINR Dubna)*
18:30	End	

Heavy Ion Physics at LHC

- 5.5 TeV Pb-Pb collisions at $L=10^{27}$ (8kHz)

  (RHIC → 200 GeV)
- run for "few" days in 2007, longer nb^{-1} in 2008.

  - Initial energy density about 5 times higher than at RHIC.
  - Lifetime of a hot & dense matter much longer

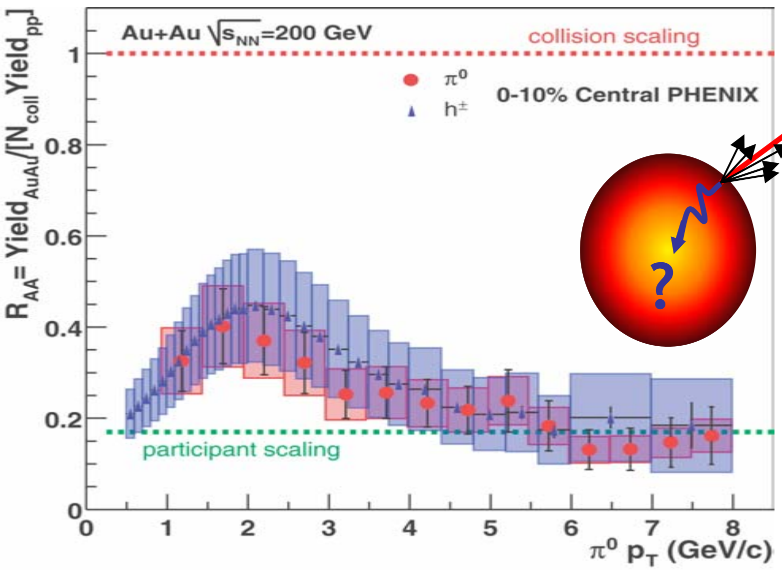
    10-15 fm/c at LHC as compared to 1.5-4 fm/c at RHIC
  - Access to truly hard probes with sufficiently high rates

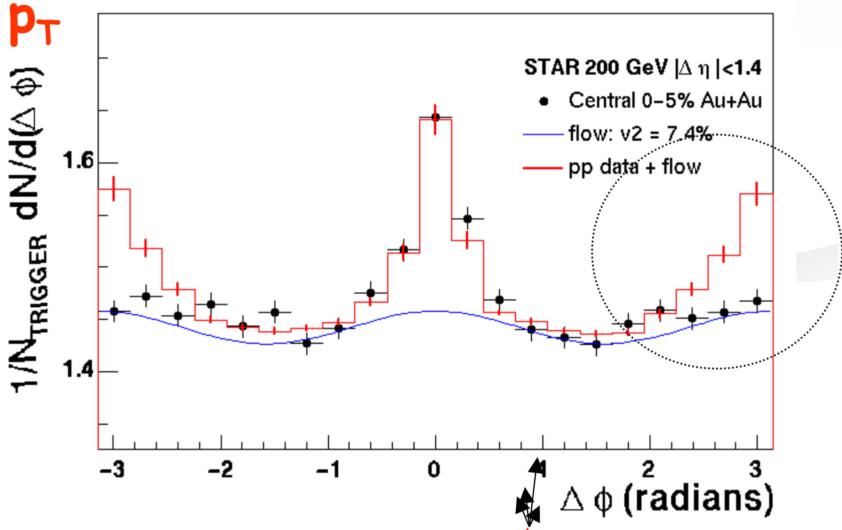
    p_T > 100 GeV/c (at RHIC $p_T \leq$ 20 GeV/c)

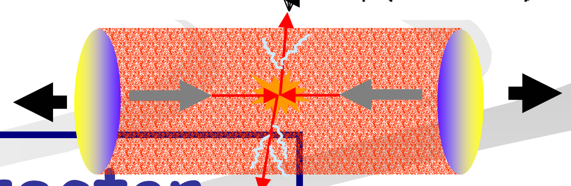
    copious production of b and c quarks
  - *LHC will access a Q^2 regime where perturbative QCD is thought to become much more quantitatively precise than at RHIC*
- Large US contingent (BNL, Columbia…), LoI submitted to DOE last year. Submission to CERN this summer.

Heavy Ion Physics with ATLAS

- "Evidence from d+Au measurements for final-state suppression of high pT hadrons in Au+Au collisions at RHIC", announced by LBL's Peter Jacob's yesterday.
- Disappearance of back-to-back high p_T jet correlations
- Huge azimuthal asymmetry at high p_T





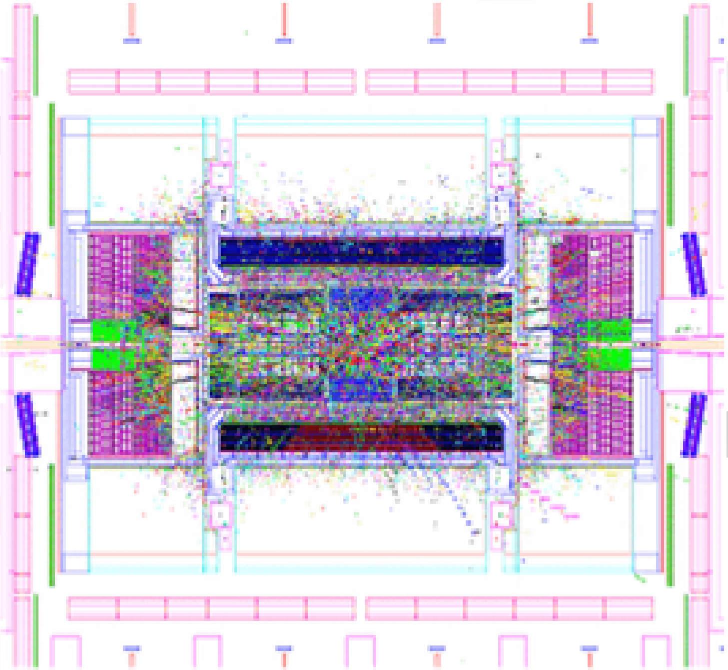


ATLAS is an excellent detector for high p_T physics and jet studies

ATLAS HI

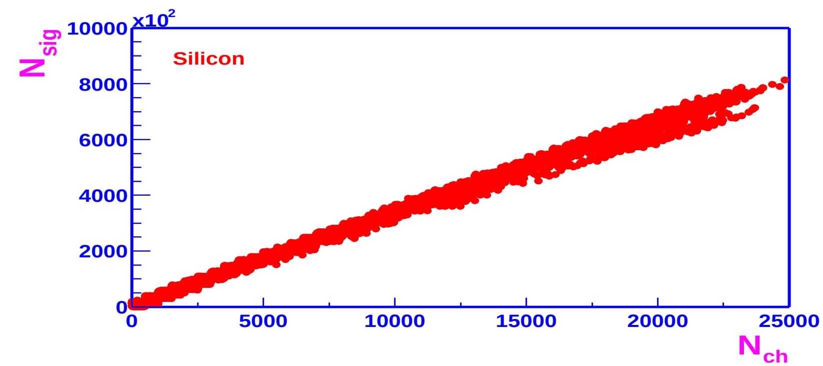
- *(largely by chance)* ATLAS is a great HI Detector for studying HARD PROBES.
  - hermetic (ALICE is not)
  - finely segmented Calorimetry
  - large acceptance muon system

    (heavy quark quarkonium suppression Upsilon→μμ resonances)
  - Si Tracker
- HI Simulations:
  - Pythia events embedded in HIJING → G3 → ATRECON.
- Can we track?
  - < 1% occupancy in pixels
  - < 20% in strips
  - TRT unusable.

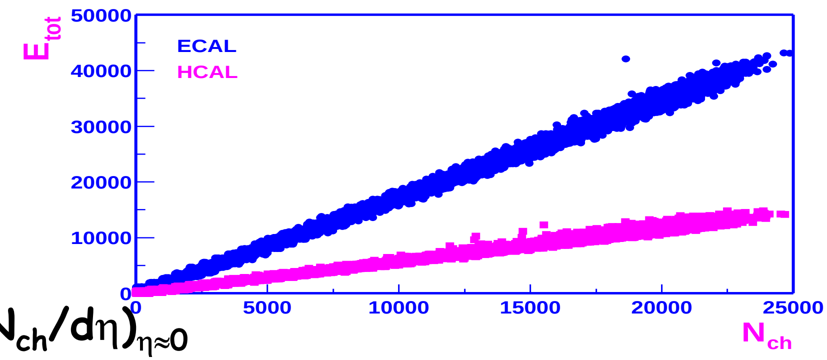


Global Measurements

One day measurements:
N_{ch}, $dN_{ch}/d\eta$, ΣE_T, $dE_T/d\eta$, b



- Constrain model prediction
- Indispensable for all physics analyses



This is new territory, the predictions for $(dN_{ch}/d\eta)_{\eta\approx 0}$ dN/dη are all over the place:

~ 6500	HIJING:with quenching, with shadowing
~ 3200	HIJING:no quenching, with shadowing
~ 2300	Saturation Model (Kharzeev & Nardi)
~ 1500	Extrapolation from lower energy data

B-jet Tagging in HI

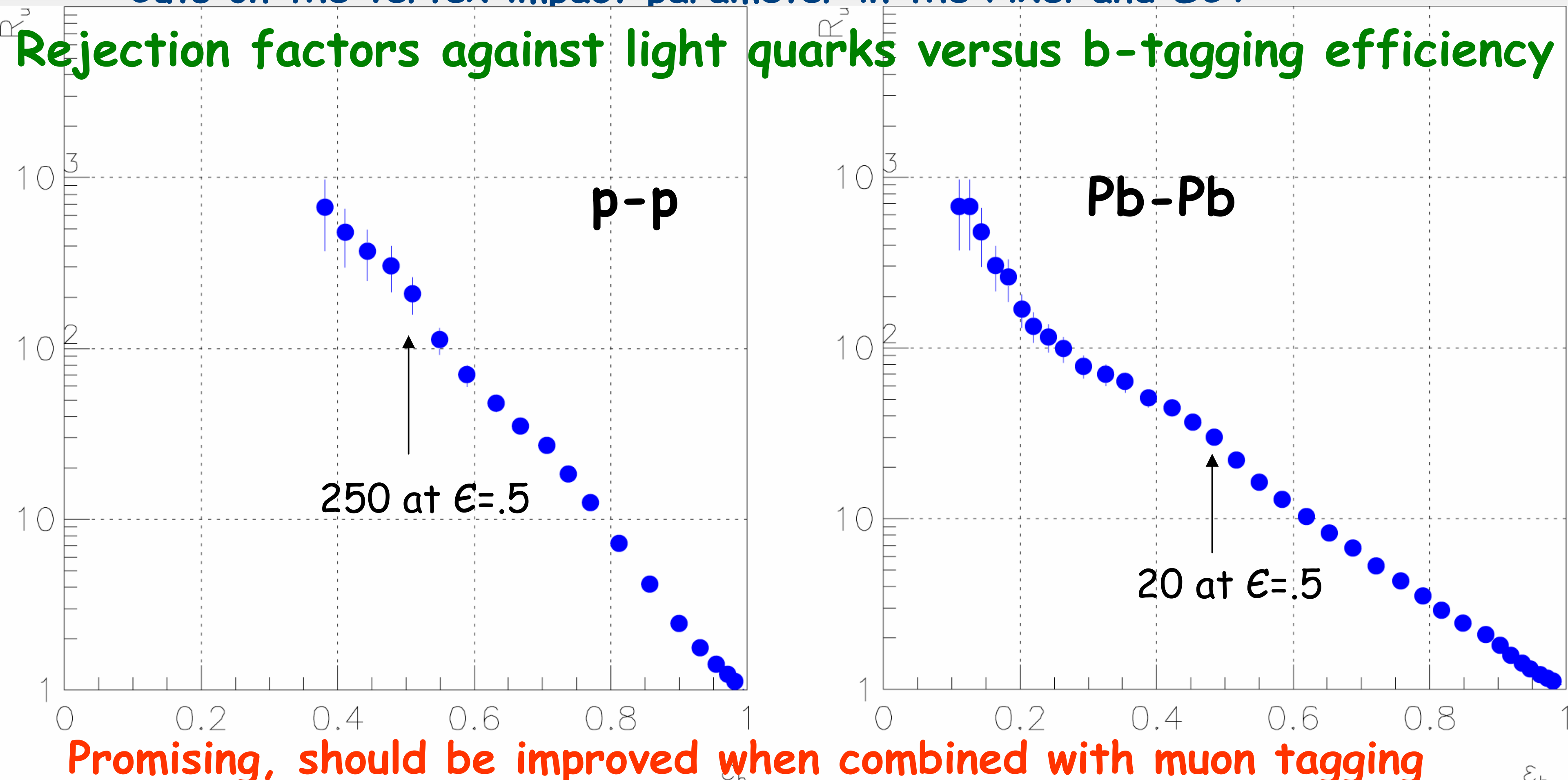
Preliminary study:

—Standard ATLAS algorithm for pp

—Higgs events embedded into pp or Pb-Pb event

—Cuts on the vertex impact parameter in the Pixel and SCT

Rejection factors against light quarks versus b-tagging efficiency



Promising, should be improved when combined with muon tagging

Heavy Ions

- ATLAS is ideal for examining Heavy Ion collisions using "Hard (high P_T) probes"
- tracking is feasible with the pixels and strips (<1,20% occupancy)
  - lots of good physics to do even from day one using simply the number of hits.
- tracking with the muon system up to P_T=15-20 GeV (need to work harder above that) (not shown)
  - important for Upsilon resonances → μ μ
- b-tagging is feasible, but rejection factors are considerably lower than for p-p
- Demonstrated jet reconstruction above E_T=40 GeV
  - jet quenching (not shown)
- ATLAS plans to submit letter of intent to CERN this summer

Heavy Ions (15:30->16:10)		**Chair:** Takai, H. **Location:** Athens University
15:30	Event characterisation, tracking, Y --> mu-mu (25') (more information)	**Wosiek, B.** *(INP Cracow)*
15:55	Jet quenching (15') (transparencies)	**Assamagan, K.** *(BNL)*

Forward physics (16:10->16:30)		**Chair:** Takai, H. **Location:** Athens University
16:10	ATLAS potential for Forward Physics (20') (transparencies)	**Rijssenbeek, M.** *(Stony Brook)*
16:30	Coffee break	

Standard Model physics (17:00->18:30)		**Chair:** Dobbs, M. and Tapprogge, S. **Location:** Athens University
17:00	Introduction (15') (transparencies)	**Dobbs M., Tapprogge S.** *(LBNL, Helsinki)*
17:20	Minimum Bias and Underlying Event (20') (transparencies)	**Moraes, A.** *(Sheffield)*
17:40	PDFs for the first year of ATLAS physics (20') (transparencies)	**Butterworth, J.** *(UCL)*
18:05	WW scattering in the absence of a light higgs (15') (transparencies)	**Cox, B.** *(Manchester)*
18:20	Wavelet analysis of VHM events in ATLAS (10') (more information)	**Uzhinsky, V.** *(JINR Dubna)*
18:30	End	

Example of commissioning our understanding of the physics environment.

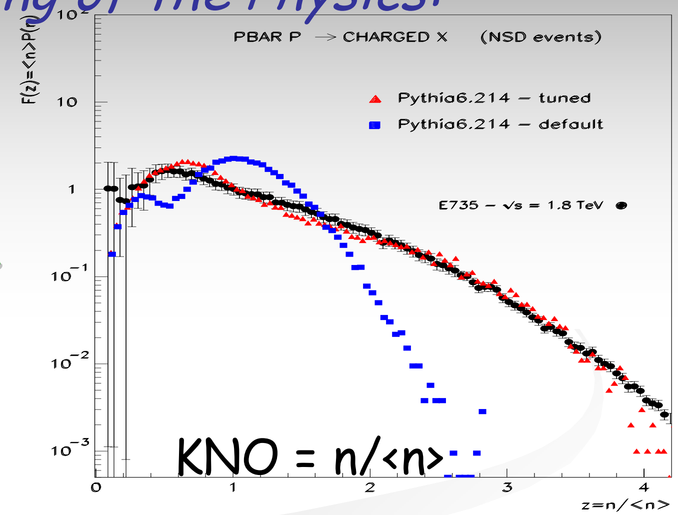
Min Bias / Underlying Event

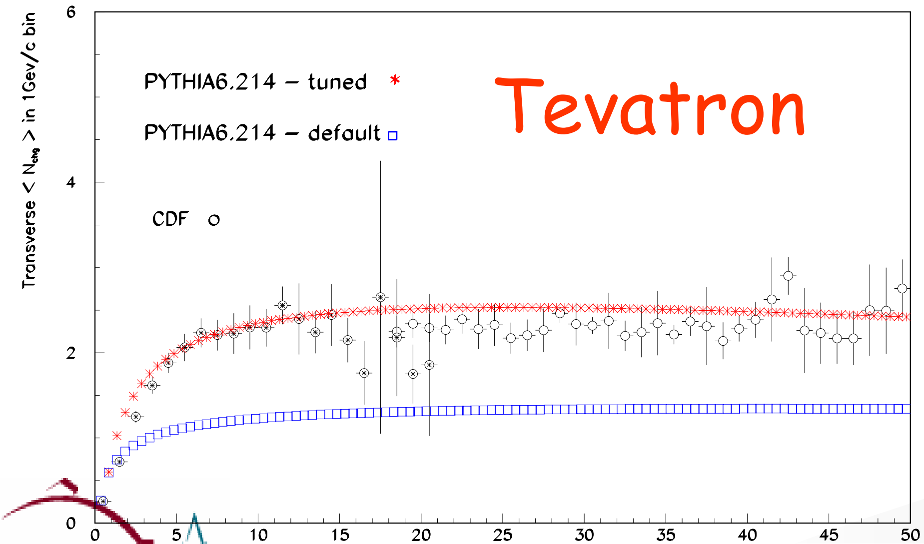
Example of Commissioning our understanding of the Physics:

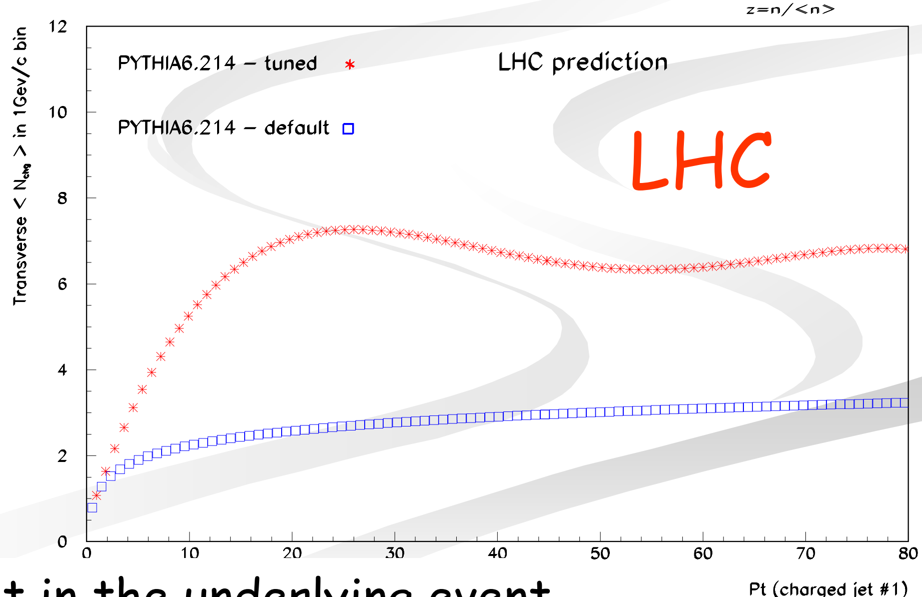
Extrapolating Predictions for minimum Bias and the Underlying Event to 14 TeV

→ *very sensitive to the Monte Carlo tune.*

has big effect on the way we reconstruct (i.e. forward jets in vector boson fusion)







P_T of away side jet in the underlying event

Friday 23 May 2003

B-physics (09:00->11:00)	Chair: Eerola, P. Location: Athens University
09:00 Introduction (10') (transparencies)	Eerola, P (Lund)
09:10 B-physics trigger studies (20') (transparencies)	Ghete, V (Innsbruck)
09:30 B -> K* gamma (15') (transparencies)	Malek-Ohlssen, F on behalf of Viret, S (Grenoble)
09:45 B_c studies (15') (transparencies)	Driouichi, C (Lund)
10:00 B_s oscillations (15') (transparencies)	Nairz, A on behalf of Innsbruck group (CERN)
10:15 B_s -> J/psi phi (15') (transparencies)	Bouhova, E (Lancaster)
10:30 Rare B -> mu+mu-(X) decays (10') (transparencies)	Eerola, P on behalf of Moscow State group (Lund)
10:40 Inner Detector performance with B-physics (15') (transparencies)	Smizanska, M (Lancaster)

illustrate performance change of new layout and staging

B Physics

- Challenging time for B-physics
  - detector layout changes affecting b-physics most
    - larger beam pipe, larger pixel size in b-layer, missing pixel and TRT layers/discs
  - HLT staging compromises b-physics trigger rate
  - → affects in "Low luminosity" period, when b-physics lives
    - low lumi → $2 \cdot 10^{33}$ $cm^{-2}s^{-1}$
- old style selection:
    - $\mu^{\pm}$ P_T>3 GeV,
    - $e^{\pm}$ P_T > 1 GeV
    - objects (J/Ψ, …) from Event filter

1% of LHC collisions will produce a bb pair!

- new strategy:
  - require at LVL1, in addition to single *μ* trigger, a second muon, a JET or an EM ROI, then reconstruct at LVL2 and EF within ROI
  - Start with a di-muon trigger for higher luminosities LHC fills.
  - Add further triggers (hadronic final states, final states with electrons and muons): in the beam coast for the low luminosity fills.
  - always fill the available bandwith in the HLT system.

B_s Oscillations, $B^0_s \to D^-_s \pi^+$

$\phi\pi$

K^+K^-

B^0_s and $\bar{B}^0_s$ are superpositions of two mass eigenstates B_H, B_L.

flavour non-conservation in charged weak-current interactions

$\Longrightarrow B^0_s \rightleftarrows \bar{B}^0_s$ transitions with frequency $\propto \Delta m_s \equiv m_{\mathrm{H}} - m_{\mathrm{L}}$

Experimental status:

- $B^0_s - \bar{B}^0_s$ oscillations not yet observed
- Combined LEP & Tevatron limits
  - PDG 2002, published results

    $\Delta m_s > 13.1\ \mathrm{ps}^{-1}$ @ 95% CL, sensitivity @ 95% CL of $13.3\ \mathrm{ps}^{-1}$

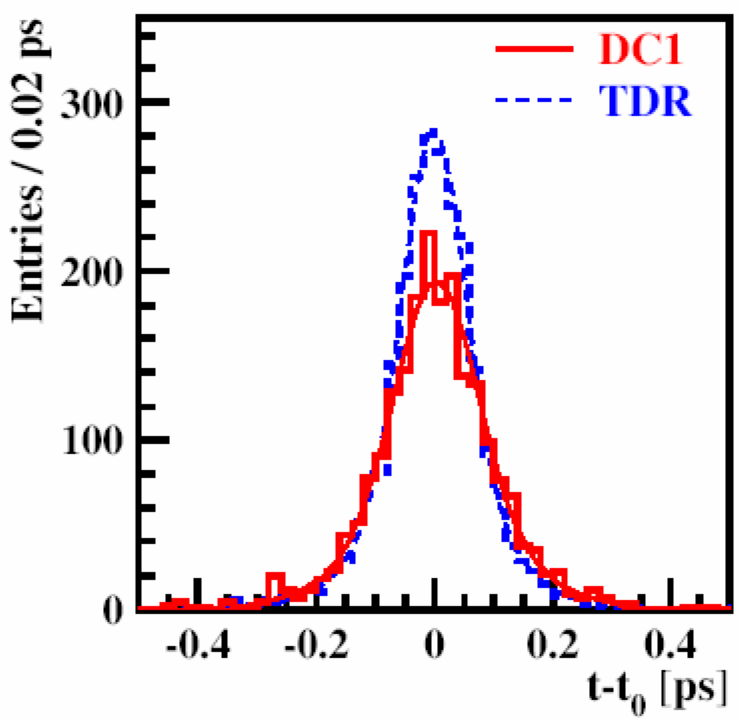
- **expectation: "difficult for SM to accommodate Δm_s above ~ 25 ps^{-1}"**
- **'old' ATLAS reach with 30 fb^{-1} → 29.5 ps^{-1} (5σ)** **EPGdirect CN3 (2002) 1**

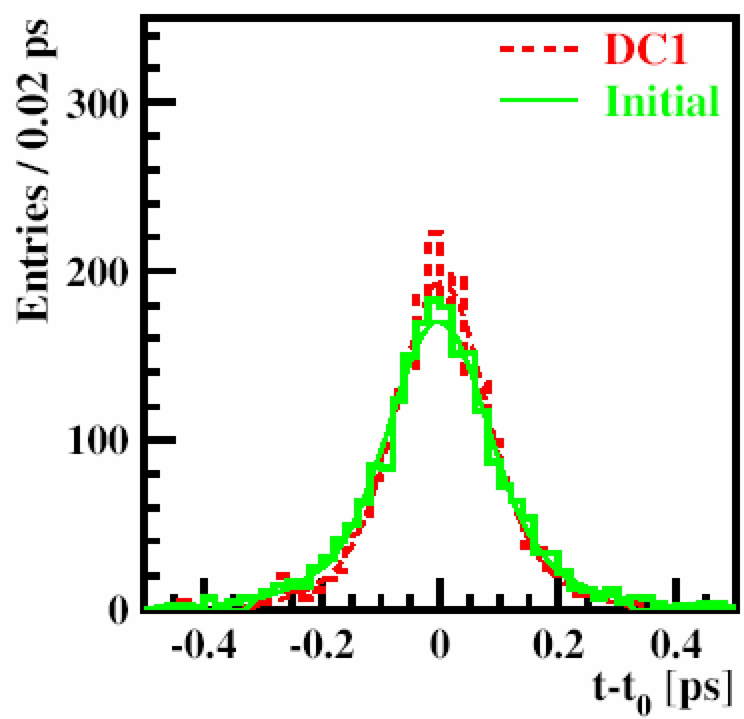
- $B^0_d - \bar{B}^0_d$ oscillations well-measured: $\Delta m_d = 0.489 \pm 0.008\ \mathrm{ps}^{-1}$

measurement requires good proper-time resolution (good impact-parameter, *pT* resolutions) which strongly depend on the detector geometry.

Affect of Layout changes on Proper time resolution

- 25%("DC1 layout") - 50%(initial layout) degradation in B^0_s proper time resolution
  - (similar result for $B^0_s \rightarrow J/\Psi\ K^0_s$ analysis)
- Δm_s resolution typically scales as $1/\sigma_t(B^0_s)$
  - implies Δm_s > 30 ps^{-1} → 20-24 ps^{-1} for staged ATLAS with 30 fb^{-1}





- detector layout changes and staging has substantially reduced the ATLAS potential for precision b-physics measurements such as Δm_s
  - This is not just a trigger issue—even if the events were there on tape, the detector performance is also degraded.
- Note that the ATLAS potential for rare decays is largely unaffected, since many of those channels are "self-triggering" (di-muon final states). ATLAS will be an excellent place to study rare B-decays

The expected signals and backgrounds for rare muonic decays; 30 fb^{-1} corresponds to three years low-luminosity running and 130 fb^{-1} to an additional one year at high luminosity

Channel	B.R.	Signal	Background
After 30 fb^{-1}			
$B_d \rightarrow \rho^0 \mu\mu$	10^{-7}	220	950
$B_d \rightarrow K^{*0} \mu\mu$	1.5×10^{-6}	2000	290
$B_s \rightarrow \phi^0 \mu\mu$	10^{-6}	410	140
After 130 fb^{-1}			
$B_d \rightarrow \mu\mu$	1.5×10^{-10}	18	753
$B_s \rightarrow \mu\mu$	3.5×10^{-9}	119	753

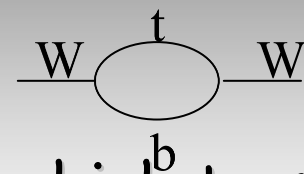
limit $BR(B_d \rightarrow \mu\mu) < 3 \cdot 10^{-10}$

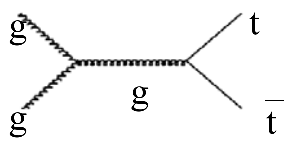
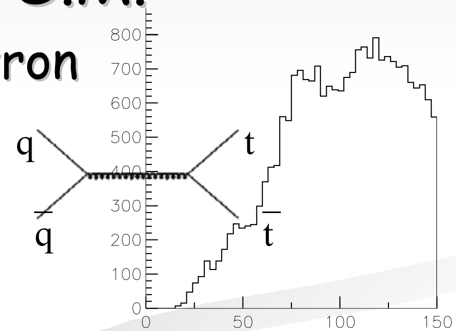
4.3σ observation

Top physics (11:30->13:00)		Chair: Cobal, M. and Parsons, J. Location: Athens University
11:30	Introduction (15') (transparencies)	Parsons, J. *(Nevis, Columbia)*
11:45	measurement of top mass (15') (transparencies)	Cobal, M. *(University of Udine)*
12:00	Top reconstruction with DC1 data (15') (transparencies)	Kostioukhine, V. *(CPPM Marseille)*
12:15	KK gravitons and top (15') (transparencies more information)	Simak, V. *(Czech Technical University)*
12:30	ttbar spin correlations (15') (transparencies)	Smolek, K. *(Czech Technical University)*
12:45	Measurement of the top electric charge (15') (transparencies)	Tokar, S. *(Comenius University)*
13:00	Lunch	

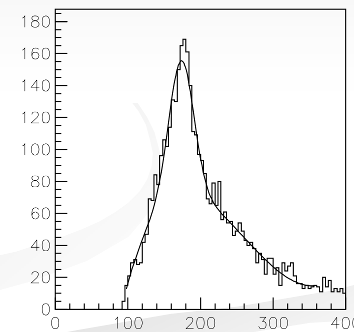
Now that CDF and D0 have proven that the top quark STILL EXISTS, what can we, at the LHC, do with it?

Top Physics

- M_{top}
  - fundamental role for radiative  corrections

  - is big → unique window through which to study fermion physics and probe beyond the S.M.
- σ_{tt}^{LHC} = 833 pb = $100 \cdot \sigma_{tt}^{Tevatron}$
  - σ_{tt}^{LHC} = 90%  + 10% 

    - (reverse at Tevatron)
  - Measure σ_{tt} to < 10% (stat.) with few days of lumi !!
    - even without b-tagging
    - Fit to m(jjb) spectrum provides σ measurement $\Delta\sigma_{stat}$ < 7%
    - important for
      - jet scale calibration with W→jj, measurement of E_T^{miss}
      - study of high P_T isolated $e^\pm$, $\mu^\pm$
      - b-tagging commissioning, optimization and efficiency evaluation



The view from on TOP

Top Mass is fundamental Parameter

$$M_W = \sqrt{\left(\frac{\pi\alpha_{em}}{\sqrt{2}G_F}\right)} \frac{1}{\sin\theta_W \sqrt{1-\Delta r}}$$

(expectation, δM_W~15 MeV)

$f(m_{top}^2, \log m_H)$ radiative corrections

special role as *the* heavy fermion.

since G_F, a_{EM}, $\sin\theta_W$ are known with high precision, precise measurements of m_{top} and m_W allow constraining Higgs mass (weakly because of logarithmic dependence)

In the single lepton channel, where we plan to measure m(top) with the best precision:

Period	evts	δM_{top}(stat)
1 year	3×10^5	0.1 GeV
1 month	7.5×10^4	0.2 GeV
1 week	1.9×10^3	0.4 GeV

Top Mass Measurement

semi-leptonic

- clean sample

  background dominated by combinatorics
- only one top reconstr.
  - BR~30%,
  - ~2.5x10^6 evts
- Kinematic fit
  - Selection effic. = 5%
  - 126k evts/10 fb^{-1}
  - S/B ~65
  - Δm_{syst} = 0.9 GeV
    - b-jet energy scale and FSR dominate

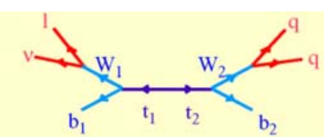
pure hadronic channel

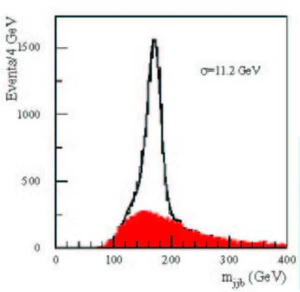
- huge QCD background
- both tops reconstructed
  - BR~44%,
  - ~3.5x10^6 evts
- High pT (t) > 200 GeV selection & kinematic fit (M_W and M_{t1}=M_{t2} constraints)
  - 3300 evts/10 fb^{-1}
  - S/B = 18/1
  - Δm_{stat} = 0.2 GeV
  - Δm_{syst} = 3 GeV

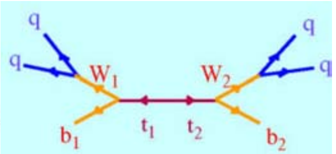
dilepton channel

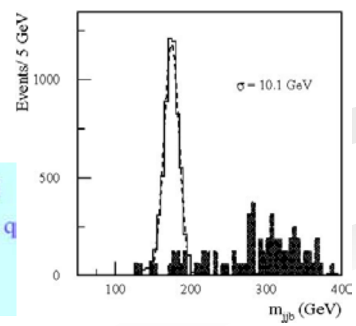
- pure sample
- indirect M_t measurement
  - BR~5%,
  - ~0.4x10^6 evts
- M_t estimator based on maximum MC probability
  - 80000 evts/ 10 fb^{-1}
  - S/B =10
  - Δm_{syst} = 1.7 GeV

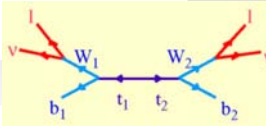
    (PDF, b-quark Frag. dominates)

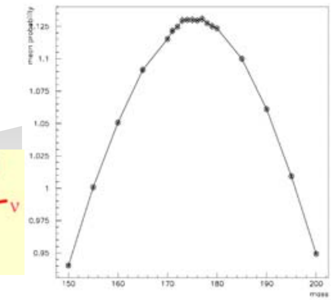






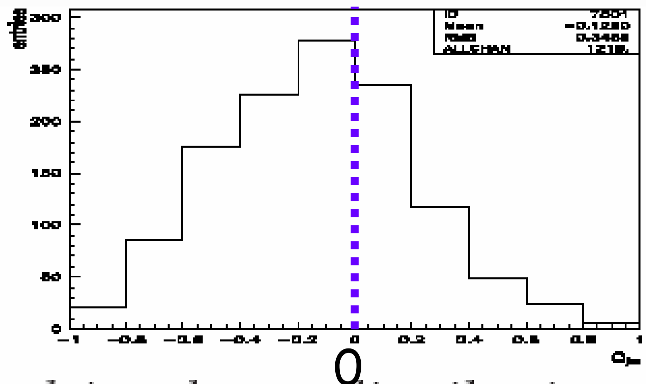




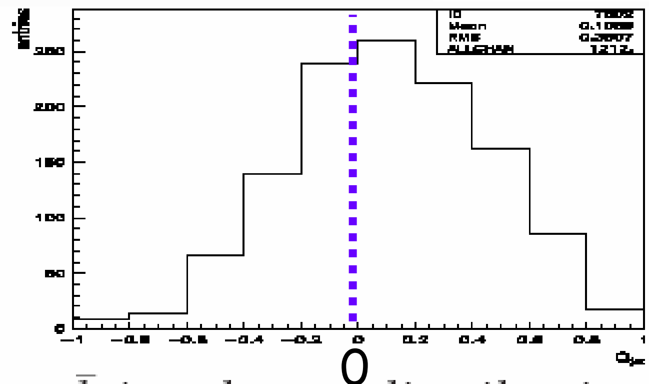


Measurement of top quark charge

- Tevatron discovery of top does not exclude an exotic top with charge -4/3.
- Two methods:
  - measure the momentum weighted b-jet charge $q_{bjet} = \frac{\sum_i q_i |\vec{j} \cdot \vec{p}_i|^\kappa}{\sum_i |\vec{j} \cdot \vec{p}_i|^\kappa}$



b-jet charge distribution



$\bar{b}$-jet charge distribution

Mean b-jet charges :

$$q(b_{jet}) = -0.109 \pm 0.007 \qquad \textbf{and} \qquad q(\bar{b}_{jet}) = 0.112 \pm 0.007$$

  - measure the ttγ cross section, $\sigma \; \alpha \; Q_t^2$

Measurement of top quark charge

- Measure top quark charge with $\sigma(tt\gamma) \propto Q^2$

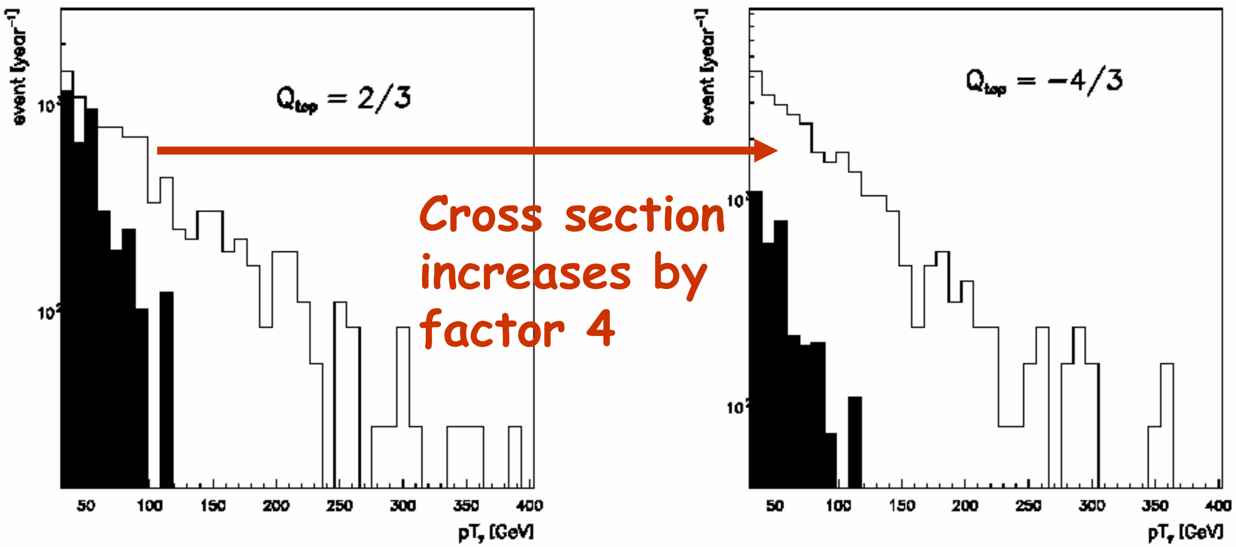


Figure 6: S vs. $p_{T\gamma}$ $(Q_t = \frac{2}{3})$ Figure 7: S vs. $p_{T\gamma}$ $(Q_t = -\frac{4}{3})$

- reduce systematics by measuring ratio $\sigma(tt\gamma)/\sigma(tt)$

process	$Q = 2/3$		$Q = -4/3$	
	$\sigma_{seen}[fb]$	events (1 year)	$\sigma_{seen}[fb]$	events (1 year)
$pp \rightarrow t\bar{t}\gamma$	7.81	78.1	24.81	248.1
$pp \rightarrow t\bar{t};\ t \rightarrow Wb\gamma$	0.62	6.2	0.244	2.4
Q_{top} indep. bkgd	6.65	66.5	6.65	66.5